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HEAT RESISTANCE OF PORTLAND FLY ASH CEMENT

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CEMENT:
FLY ASH

Hydrated Portland cement contains a large amount of calcium hydroxide ($C_a(OH)2$), which gets hydrated to calcium oxide (CaO) between 500-600 ^{o}C. On cooling and exposure to moist air or wetting, the CaO rehydrates to Ca (OH)2 with a volume expansion of 97 percent. This leads to the formation of cracks or total disruption of the set cement which has withstood high temperature without actual disintegration. The heat resistance of Portland cement is thus very poor. Addition of finely divided materials such as dehydrated aluminium silicate (fireclay), natural hydrated aluminium silicate (clay), Chromite, sintered magnesite, slag, silica, diatomaceous earth, etc, in Portland Cement is known to stabilise and increase heat resistance by combining with free CaO.

The heat resistance of Portland fly ash cement vis-a-vis ordinary Portland Cement was evaluated by studying the effect of (i) heat up to 1200 ^{o}C on compressive strength and free CaO content and (ii) alternate heating and exposure to high humidity. The results obtained are reported.

Materials Used

Portland Cement: It conformed to the specified chemical and physical requirements of IS:269-1967 for ordinary Portland Cement.

Fly Ash: It was obtained from 'C' thermal power station, Delhi. Its chemical composition and physical properties conformed to IS:3812 (Part I):- 1966.

Portland Fly Ash Cement: It contained 20 to 30 percent fly ash by weight. It was produced in the laboratory by intimately blending together required quantities of Portland cement and fly ash.

Test Procedures

Determination of effect of heat on compressive strength 1.25 cm cubes were cast using pastes of Portland cement and Portland fly ash cement at standard consistency. They were demoulded after 24 hours of moist storage (over 90 percent rel. humidity and 27 ± 2°C and cured for 6 days under water at 27 ± 2°C. The wet cubes were dried at 110°C before heating them in an electric muffle furnace at 400, 600, 800, 900, 1000 and 1200°C. On cooling, their compressive strength was determined in the usual way.

Estimation of free CaO content: The content of free CaO in hydrated Portland and Portland fly ash cement heated at different temperatures under was estimated by the method specified in IS:4032-1968.

Determination of effect of alternate heating and exposure to high humidity: One cycle of alternate heating and exposure to high humidity consisted of heating 1.25 cm cubes of Portland and Portland fly ash cement for 4 hours and on cooling exposing them to high humidity (over 95 percent rel. humidity) at 27 ± 2 °C for 7 days. Test specimens cast and cured as described under (1) were subjected to 5 cycles of alternate heating at different temperatures and exposures to high humidity. The performance criteria was based on failure by cracking observed visually.

Results and Discussions

Effect of heat on compressive strength: Data on relative cold compressive strength of hydrated Portland and Portland fly ash cement dried at 110°C and subsequently heated at 400, 600, 800, 1000 and 1200°C is shown in fig 1.

There is sharp fall in strength with rise in heating temperature upto about 1000°C. The maximum damage appears to have occurred around 1000°C. At this temperature the strength of Portland cement and Portland fly ash cement containing 20 percent and 30 percent fly ash,

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by weight, dropped to 22.7, 21.7 and 17.3 percent of the strength obtained on specimens dried at 110°C. A recovery in strength due to ceramic bonding is noticeable on heating above 1000°C. While the recovery in strength of Portland fly ash cement is quite appreciable, it is only marginal in case of Portland cement.

Effect of heat on free CaO content: Table 1 shows contents of free CaO estimated in hydrated Portland and Portland fly ash cement heated at different temperatures. As compared to about 5 percent CaO content in Portland cement heated at 800-1200°C, there is progressive decrease in free CaO content in Portland fly ash cement with rise in the heating temperature.

The free CaO in Portland fly ash cement is considered to react with SiO_2, Al_2O_3 and Fe_2O_3 present in the fly ash on heating.

A vitreous phase is formed above 1000°C. On cooling the vitreous phase develops a ceramic bond with consequent increase in strength (fig. 1).

Effect of alternate heating exposure to high humidity. The condition of test cubes after 5 cycles of alternate heating and exposure to high humidity is shown in fig.2.

Cubes made of Portland cement and heated at 800, 900 and 1000°C cracked within 2 days of exposure to high humidity in the first cycle itself. Cubes made of Portland fly ash cement and heated at 800°C developed cracks after 6 days of exposure to high humidity in the first cycle. But cubes made of Portland fly ash cement and heated at 900 and 1000°C showed good volume stability and withstood 5 cycles of alternate heating and exposure to high humidity without any sign of cracking.

Dimensional changes in the cubes occurring during the first cycle of alternate heating and exposure to high humidity are shown in Table 2.

The Portland fly ash cement undergoes lesser shrinkage on heating than Portland cement. This can be attributed to its lower content of cement and its hydration products and to the restraining effect of fly ash.

The effect of fixation of free CaO by reaction with the fly ash constituents is clearly evident from the expansion occuring in Portland fly ash cement on exposure to high humidity. While with free CaO content of about 1.3 percent or more (Table 1), the cubes cracked, the expansion shown by uncracked cubes decreased with decrease in free CaO content.

The dimensional changes in the uncracked cubes were found to be reversible in the subsequent cycles of alternate heating and exposure to high humidity.

Conclusion

The study shows that Portland fly ash cement containing 20 to 30 percent fly ash, by weight, possesses good heat resistance and volume stability at high temperatures vis-a-vis Portland cement which develops cracks due to rehydration of CaO on exposure to high humidity. It can, therefore, be used to produce heat-resistant mortars and concretes which are likely to be exposed to a temperature of 900-1000°C.

Acknowledgment

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Table: 1 Free Cao content in Portland fly ash cement heated at different temperatures.

Cementing Material	Heating Temperature °C	Free Cao Content %
Portland Cement	800	5.067
	900	5.067
	1000	5.079
	1200	5.071
Portland fly ash Cement (20% fly ash)	800	1.298
	900	0.779
	1000	0.260
	1200	0.259
Portland fly ash Cement (30% fly ash)	800	1.284
	900	0.649
	1000	0.247
	1200	0.241

Table 2. Dimensional changes in Portland and Portland fly ash cement in the first cycle of alternate heating and exposure to high humidity.

Cementing Material	Heating Temperature °C	Dimensional Changes Shrinkage %	Expansion %
Portland Cement	800	2.179	cracked
	900	2.259	cracked
	1000	2.755	cracked
Portland fly ash cement (20% fly ash)	800	1.485	cracked
	900	1.888	0.227
	1000	2.315	0.165
Portland fly ash cement (30% fly ash)	800	1.413	cracked
	900	1.672	0.132
	1000	2.110	0.065